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Public Sector Pricing in a Fiscal Context

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If administered prices are to generate revenues, they should deviate from marginal cost and should be determined on the basis of their economy-wide effects, without regard to financial targets. It is better to raise prices above marginal cost through taxes than by raising the price received by the enterprise.

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Administered prices should deviate from marginal cost if they are to be used as instruments to generate revenue.

The analysis is based on the Bank's two-step approach to public sector pricing: first calculating marginal cost, and then adjusting it to account for other factors. The aim is to show how those adjustments should be made to account for fiscal concerns. Such adjustments are not widely used at present.

The appropriate basis for pricing in the first step, the author contends, is a weighted average of short and long-term marginal costs.

Deviations from marginal cost in the second step are shown to depend on their revenue-raising, distortionary, and distributional effects.

Imposing financial constraints may be an inefficient method of achieving fiscal objectives. It is better to decide prices on the basis of their economy-wide effects without regard to financial targets — and then, if necessary, to impose financial targets that are consistent with those prices.

The author argues that it is better to raise prices above marginal cost through taxes than by raising the price received by the enterprise.

Metering problems prevent direct observation of the use of publicly produced goods — a problem that particularly affects road user charges. The author discusses how to set charges in the face of metering difficulties, stressing the need to set uniform charges and to make indirect charges on inputs.

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PUBLIC SECTOR PRICING IN A FISCAL CONTEXT

by

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EXECUTIVE SUMMARY

The purpose of this paper is to set out the principles that should underlie the setting of public sector prices in LDCs, and specify the data requirements for applying those principles. The paper pays particular attention to the use of public sector prices as instruments of revenue-generation for the central government, and thus reflects the current concern over budgetary problems in LDCs. Although the principles discussed in the paper apply to all parts of the public sector, special consideration is given to the problems of pricing in the transport sector.

The analysis adopts the Bank's two step approach to public sector pricing: first calculating marginal cost, and then adjusting it to take account of other factors. Adjustments for fiscal reasons are not widely used at present, perhaps partly because the methods for making such adjustments are not widely known. This paper sets out the techniques that should be applied.

As the two step approach requires an initial calculation of marginal cost, the paper starts with a consideration of the appropriate concept of marginal cost. Should short-run or long-run marginal cost be used? The paper argues for the use of short-run marginal cost pricing because of its ability to promote the full use of productive capacity. However, the argument rests on the ability to change prices when capacity utilization changes, and the appropriate definition of the short-run is therefore the period over which prices cannot be changed.

The greater variability in prices based on short-run marginal cost (as compared to prices based on some concept of long-run marginal cost) can cause difficulty for some consumers who require knowledge of future prices. The importance of this consideration varies from one industry to another. For those industries where it is important, a weighted average of short and long-run marginal cost can be used, with the weights reflecting the relative importance of capacity utilization and price stability.

The paper then turns to fiscal considerations and shows that the imposition of financial constraints on enterprises can be an inefficient method of achieving fiscal objectives, because they neglect the differences in the distortionary costs of raising revenue in different industries. It is better to decide prices on the basis of their economy-wide effects without regard to financial targets. If financial targets are important in providing incentives to enterprises, the levels of these targets can then be determined on the basis of the pricing policy that is best for each enterprise. Such an approach would reverse a common situation where prices are determined by financial constraints.

The paper shows how prices can be decided using information on their revenue-raising, distortionary and distributional effects. The consideration of distortionary effects shows that it is generally better to raise price above marginal costs only in sales to final consumers. The raising of prices in sales to firms can yield the same revenue but will have a greater distortionary cost. However, it is often impractical to tax final sales and the taxation of intermediates can then be a useful revenue source.

It is also shown that the raising of the price received by enterprises may produce an incentive for inefficient investment. It is therefore better to raise consumer prices by the use of taxes whenever this is possible.

The final section of the paper looks at the consequences of metering problems that prevent the direct observation of the use of publicly produced goods. This is a problem that particularly affects road transport and the discussion therefore concentrates on the setting of road user charges. There are two related problems. First, it is difficult to tax the use of different roads at different rates. Second, it is difficult to tax road use directly and so inputs into road use must be taxed instead.

In relation to the first difficulty, the paper shows that where different road uses must be charged at the same rate, the charge should be a weighted average of the marginal cost of each road use.

In relation to the second difficulty, the paper shows that a uniform tax on the inputs into road use (gasoline, vehicles, tires, etc.) is equivalent to the same rate of tax on road use itself. It also shows how these tax rates on inputs should be modified to take account of taxes elsewhere in the economy and it demonstrates that, if some inputs cannot be taxed, the taxes on other inputs should be adjusted by a factor that depends on their substitutability with the untaxed input.

The taxes on inputs derived in this section are not distortionary; they are correcting the externality involved in road use. They are, therefore, not subject to the argument against taxing intermediate goods, and should be applied equally to firms and final consumers. However, the principles set out earlier in the paper can be used to decide on possible additional revenue-raising taxes on inputs into road use. Such additional taxes would be subject to the (qualified) argument against intermediate good taxation outlined above.

SECTION 1: INTRODUCTION

1.1 The purpose of this paper is to set out the principles that should underlie the setting of public sector prices in LDCs, and discuss the data requirements for applying those principles. The paper pays particular attention to the use of public sector prices as instruments of revenue-generation for the central government. Although the principles discussed in the paper apply to all parts of the public sector, special consideration will be given to the problems of pricing in the transport sector.

1.2 Current World Bank policy on public sector pricing is reviewed in Julius and Alicbusan (1986) and involves a two-step approach: first, marginal cost is calculated; second, marginal cost is adjusted to take account of such factors as metering problems, distributional objectives and financial objectives. While this approach is fundamentally sound, Julius and Alicbusan found that the second-step adjustments are often not made in practice. This was particularly true of adjustments to take account of the fiscal constraints facing the government. Failure to make these adjustments implies that governments are not making the best use of opportunities to raise revenue through the setting of public sector prices. Such neglect of revenue raising opportunities is serious for LDCs which typically rely heavily on taxes on international trade to raise revenue. There has been growing concern about the harmful effects of trade taxes and a resulting pressure to find other, less distortionary, sources of government revenue.

1.3 In these circumstances, the setting of public sector prices above cost has considerable attractions as a method of raising revenue, especially in countries that have difficulty operating effective general sales taxes. However, the question of whether this method should be used in a particular country depends on the viability of alternative sources of revenue and their relative distortionary effects. Even when the decision is

made to use public sector pricing to raise revenue, the extent to which individual prices should be adjusted for fiscal reasons will depend on various characteristics of the demands for the goods in question and the existence of taxes elsewhere in the economy. The factors that should govern these adjustments must be carefully articulated before the two-step approach can become operational. In addition, any policy that involves significant departures from marginal cost pricing must take account of the effect that it has on investment decisions. This paper is addressed to those two issues, and thus seeks to provide a basis for the incorporation of fiscal considerations into the setting of public sector prices.

1.4 In order to concentrate on the incorporation of fiscal considerations into public sector pricing, this paper will not address many other issues that relate to public sector pricing such as "second best" adjustments to deal with market imperfections, shadow pricing of inputs and income distribution (except in so far as higher public sector prices might affect income distribution). However, there are two issues that must be given some attention here. First, the question of whether short- or long-run marginal cost should be used in the first-step is crucial as it is the base to which all the adjustments are made. Second, no pricing recommendations can have practical application unless they take account of the practical difficulties of measuring and collecting charges for the publicly produced good, a particularly important point in the case of transport.

1.5 The plan of the paper is therefore as follows. Section 2 considers the appropriate concept of marginal cost. Section 3 discusses the way in which this marginal cost should be modified to take account of fiscal objectives. Section 4 considers how metering problems might modify the recommendations of Section 3. Section 5 provides a summary and concluding remarks.

SECTION 2: THE APPROPRIATE CONCEPT OF MARGINAL COST

2.1 The purpose of this section is to lay out the considerations that should determine the marginal cost concept to be used as a basis for the determination of public sector prices. The main issue here is whether short-run marginal cost should be used, or whether the marginal cost concept should also include some allowance for capital costs. World Bank practice in this area is not uniform: Walters (1968) recommends the use of short-run marginal cost as a basis of road user charges, while Munasinghe (1981) suggests the use of long-run marginal cost as the basis of electricity charges.

2.2 Although Saunders, Warford and Mann (1977) show that there are several ways of defining marginal cost to include capital costs, the discussion here will concentrate on the basic issue of whether they should be included at all. This section therefore starts with an explanation of the advantages of short-run marginal cost and discusses its application to transport pricing. The main argument against short-run marginal cost, price variability, is then analyzed. Finally, the relationship of pricing to investment decisions is considered.

A. The Advantages of Short-Run Marginal Cost

2.3 The argument for using short-run marginal cost as a basis for public sector pricing is most easily seen in a situation where the capital stock is fixed and the only way in which output can be altered is by changing the level of variable inputs. The social cost of producing one more unit of a good (or the benefit in producing one less unit) is then clearly the cost of the extra variable inputs required to produce an extra unit of output, in other words the short-run marginal cost. Allocative

efficiency then requires that it is this cost that should face consumers who are choosing how to allocate their expenditure.

2.4 In the long-run, changes in output may also be met by changing the quantity of capital. However that is an investment decision, to which we will turn below, and there is a real sense in which pricing decisions are always made in the "short-run". If there is spare capacity in an industry, lowering the price to short-run marginal cost will make better use of resources. The increased demand involves no commitment to capital expenditure because the price can be raised in the future if the spare capacity disappears.

2.5 The rationale for using short-run marginal cost is even clearer for an industry that is operating above design capacity. In extreme cases the industry will face an absolute limit on its output and the charging of long-run marginal cost would not clear the market without the use of rationing. In this case, short-run marginal cost is the cost to consumers of reallocating one unit of output, which is simply the market clearing price. Therefore short-run marginal cost pricing allocates the fixed output efficiently. In less extreme cases, operation above design capacity simply implies that short-run marginal cost is above long-run marginal cost. In this case the use of long-run marginal cost would involve charging a price below the social cost of extra units of output and result in misallocation of resources. The fact that output can be increased more cheaply by expanding capacity is no reason for lowering the price before the capacity has been increased.

2.6 The observation that short-run marginal cost will be greater than long-run marginal cost when a firm or industry is operating above design capacity is important in understanding how short-run marginal cost pricing allocates demand between industries. As an example, consider the allocation

of freight transport between roads and railways. Variable operating costs form a higher proportion of total operating costs for road transport than for railways and it might therefore be thought that (assuming equal average costs) railways will have a lower short-run marginal cost and would therefore take most of the freight. However, this would only necessarily be the case if both industries were operating below capacity. If the railways were operating above design capacity, short-run marginal costs (including congestion costs) will be above long-run marginal costs. In this case, short-run marginal cost pricing would induce freight to move towards road transport, unless that industry was also operating well above capacity.

2.7 It might be that the railways are operating well below capacity, and then short-run marginal cost pricing will give them a competitive advantage. However, given that there is excess capacity on the railways, short-run marginal cost pricing would produce the most efficient allocation of freight. The excess capacity might be due to mistakes or the indivisibility of investment or some other cause, but whatever the cause it provides an opportunity for (socially) inexpensive transport while it lasts.

2.8 This analysis indicates that the question of the right balance between road and rail is one that should be resolved when investments are decided. Once the investments have been made, they should be put to the best use by using short-run marginal cost pricing. Investment policy will be considered below, but first the issue of price variability must be considered.

B. The Consequences of Price Variability

2.9 The most significant criticism of the use of short-run marginal cost is that it produces prices that vary a great deal. It must of course be accepted that long-run marginal cost varies as demand changes, but not

by as much as short-run marginal cost. In fact, it is the variability of short-run marginal cost that gives it the advantages discussed above, of ensuring full utilization of existing capacity. Nonetheless, it is necessary to consider whether this price variability also has disadvantages.

2.10 There are two types of disadvantage that might follow from price variability. First, there is the administrative cost and political difficulty for the government in altering the prices. Second, there is the uncertainty for the consumer in not knowing what the price is going to be.

2.11 Before discussing each in turn, it should be noted that there are some sorts of price variability that do not involve either sort of disadvantage. For example, the use of peak-load pricing schedules¹ that set different prices for electricity or public transport at different times of day, or even different days, do not cause administrative costs (other than the metering difficulties discussed in Section 4) or political difficulty because the whole schedule can be announced at one time. The fact that the whole schedule is announced at one time also means that there is no uncertainty for the consumer. The sort of price variability that does have disadvantages are price changes whose timing is hard to predict, such as increases in short-run marginal costs as an industry approaches full capacity and falls in short-run marginal cost as capacity is increased. These changes are hard to predict for several reasons, including difficulty in predicting demand changes, poor knowledge of how marginal costs change with output and difficulties in predicting when new capacity will be ready for use.

1/ The setting of optimal two-part tariffs is discussed in Feldstein (1972b).

2.12 The administrative costs of price changes can be significant, involving a formal decision-making process and the need to disseminate information on the new prices. Such costs mean that both public enterprises and the government will not want to be continually changing prices. This will be particularly true if the government expects political difficulties in raising prices.

2.13 Any requirement that prices should remain constant for a period of time will affect the arguments advanced above in favor of short-run marginal cost pricing, because they relied on the possibility of altering prices when capacity utilization changed. Therefore, the length of time that should be regarded as "the short-run" should be the length of time over which the price cannot be changed.

2.14 For example, suppose that prices can only be changed once every six months. In such a case, the cost of increased output throughout the six month period must be considered in making pricing decisions. A three month period of excess capacity may not justify lowering prices to the temporarily low short-run marginal cost if the remaining three months will include periods of very heavy capacity utilization. In other words, an average value of short-run marginal cost must be used. A further complication is that, in some industries, six months may be long enough to permit considerable changes in capacity and so increases in output within one pricing period may be partly met by capacity increases. Thus some capital costs are included in the appropriate definition of variable costs, and therefore in short-run marginal cost. There will then be less of a distinction between short and long-run marginal cost.

and therefore in short-run marginal cost. There will then be less of a distinction between short and long-run marginal cost.

2.15 The effect of price variability on consumers is usually regarded as the more important disadvantage of short-run marginal cost pricing. The idea is that price uncertainty makes it difficult for consumers to make investment decisions that are complementary to the consumption of the publicly produced good. For example, a firm will want to know about future road use charges when deciding on the location of a factory, or a household will want to know about the future costs of different energy sources before investing in a water-heater. These examples make it clear that it is not the price variability per se that is the problem, but the lack of information. If the firm knows about future increases in road use charges the investment decision can be made properly, but if they simply think that the current low charges will continue indefinitely they will probable make the wrong decision.

2.16 These observations provide something of a case for using long-run marginal cost as a basis for pricing decisions because, as a more stable price, it contains more information about future price levels. In principle, the informational problem could be overcome without sacrificing the efficiency of short-run marginal cost pricing by making official forecasts of average future price levels. However, the forecast might lack credibility in practice.³

3/ A more useful possibility would be for the public enterprises to offer fixed price contracts at a price somewhat above the expected average price (the differential being justified by the costs of unresponsive demand). This might be attractive to purchasers for whom price variability is a particularly serious problem.

2.17 It is difficult to quantify the effects of uncertainty produced by short-run marginal cost pricing because of the difficulty of knowing how people form their price expectations. However, some qualitative observations can be made. First, the advantages of short-run marginal cost pricing are greater in those cases where capacity is different from demand for long periods of time. Second, the costs of errors in price expectations are more serious where the investment significantly constrains future choice. The first observation gives weight to Walter's suggestion of using short-run marginal cost in road user charges, because of the long time often required to undertake investment in new roads. The second observation gives weight to the idea of using long-run marginal cost for electricity, because investment in electrical equipment commits the owner to that energy source for some considerable time.

2.18 In principle, the informational problem could be overcome without sacrificing the efficiency of short-run marginal cost pricing, by making official forecasts of average future price levels. However, the forecast might lack credibility in practice. A more useful possibility would be for public enterprises to offer fixed price contracts at a price somewhat above the expected average price (the differential being justified by the costs of unresponsive demand). This might be attractive to purchasers for whom price variability is a particularly serious problem.

2.19 It is difficult to quantify the effects of uncertainty produced by short-run marginal cost pricing because of the difficulty of knowing how people form their price expectations. However, some qualitative observations can be made. First, the advantages of short-run marginal cost pricing are greater in those cases where capacity is different from demand for long periods of time. Second, the costs of errors in price expectations are more serious where the investment significantly constrains

relationship with pricing policy, issues of uncertainty, irreversibility and adjustment costs are ignored. Their relevance to investment theory is explained in Nickell (1978).

2.20 Consider first the case of infinitely divisible investment. If short-run marginal cost is used for pricing, any extra investment will be fully used and the criterion for investment is simply that the value of extra output is as great as its cost. This is equivalent to requiring that the price should be as great as the long-run marginal cost. But as price is equal to short-run marginal cost, this means that investment should be undertaken whenever short-run marginal cost is above long-run marginal cost. If long-run marginal cost is used for pricing, output will not be directly affected by investment. Instead, investment should be viewed as a possible method of reducing the cost of output, the level of which is determined by the quantity demanded at a price equal to long-run marginal cost. Additional investment will reduce cost if output is higher than the level at which short and long-run average cost are equal. But at that level of output, short-run marginal cost is higher than long-run marginal cost. Thus the investment criteria are the same, whichever pricing rule is used.

2.21 This similarity in investment rules in the case of infinitely divisible investment is not really surprising because, under the optimal investment rule, short-run and long-run marginal costs are equal. If capacity is always adjusted so that long and short-run average costs are equal, then the corresponding marginal costs are equal. In other words, the two pricing rules generate the same prices so long as investment is optimal. This implies that differences in the outcomes of the pricing rules only occur if either investment is non-optimal or investment is indivisible. The implications of non-optimal investment have been considered above, and so the rest of this section will be concerned with the effect of pricing rules on indivisible investment decisions.

2.22 The indivisibility of investment implies that capacity cannot continually keep pace. Most of the time production will either be below or above the optimal level of capacity utilization. It is in these circumstances that the pricing rules have different outcomes.

2.23 If short-run marginal cost pricing is used, prices will rise as capacity utilization increases, reducing demand and moderating the extra costs of producing above design capacity. When new investment is installed there will be temporary excess capacity and prices will fall to encourage its use. The decision on the timing of the new investment is then one of comparing the costs of earlier investment with the benefits. The cost of earlier investment is the opportunity cost of diverting investment from other uses (the interest payments over the period that it is moved forward, if the capital markets are perfect). The benefit of extra investment is not simply the value of the additional product (as in the divisible case) because the price will change. Instead, it will be the increase in the sum of consumer and producer surplus.³ The optimal time for investment will be when the cost and benefit of slightly earlier (or later) investment are equal.

2.24 If long-run marginal cost pricing is used, prices will not rise and fall with capacity utilization. This means that there is no need to make producer and consumer surplus calculations in undertaking investment decisions. The only question is when should investment be timed in order to minimize the cost of production. The cost of earlier investment is the same as above, but the benefit is the reduction in production costs. As before, optimal timing is determined by the point at which the costs and benefits of slightly altered timing are equal.

3/ This is explained in Little and Mirrlees (1974).

2.25 It should be clear that, neglecting the problems of price variability, short-run marginal cost pricing leads to more efficient investment for two reasons. First, the increase in price as capacity utilization increases has the effect of reducing demand and thus preventing the need for premature investment. Second, the reduction in price after new investment is installed ensures that full advantage is taken of any excess capacity. However, it is difficult to make any prediction about which pricing rule (and associated investment rule) will produce the earlier investment. On the one hand, the fact that prices do not rise with capacity utilization means that long-run marginal cost pricing cannot delay the increase in costs associated with production above design capacity, and this increases the benefit of earlier investment. On the other hand, long-run marginal cost pricing does not allow the full exploitation of the additional capacity that has been installed, and this reduces the value of earlier investment. One can only conclude that the outcome of these conflicting tendencies will depend on the circumstances of each particular case.

SECTION 3: FISCAL AND FINANCIAL OBJECTIVES

3.1 This section addresses the main concern of the paper: the way in which public sector prices should be modified to take account of the government's fiscal constraint. In discussing this issue, it is necessary to consider the financial constraints that are often imposed on public enterprises. These financial constraints typically specify requirements such as the need to reach certain rates of return on investment or the need for the enterprise to break even. Although part of their justification is the need to provide management with simple efficiency objectives, it is clear that a major part of their justification is to ensure that the enterprises do not constitute a drain on the government's fiscal resources. In any event, they certainly have an effect on the government's fiscal position.

3.2 The section will therefore start with an analysis of the relationship between the government's fiscal constraint and the financial objectives that are set for individual enterprises. Once that has been clarified, the discussion will proceed by looking in turn at the revenue effects, the distortionary effects and the distributional effects of pricing above marginal cost. The relative advantages of taxation and higher producer prices are then considered, and the section finishes with a discussion of the data requirements for deciding on revenue-raising public sector prices.

A. The Relationship Between Fiscal and Financial Objectives

3.3 In order to clarify the relationship between fiscal and financial constraints, it is best to start by considering the government's fiscal constraint on its own and imagine an economy where public enterprises do not face financial constraints, but carry out direct government

instructions. If the government was able to levy commodity taxes on all transactions in the domestic economy, the situation would be the same as that analyzed by Diamond and Mirrlees (1971). They show that production efficiency is desirable, provided all commodity taxes are set optimally and there are no after-tax private sector profits. They also show that the pattern of commodity taxation should depend on own-price and cross-price elasticities of demand for all the goods, in a manner that will be discussed more fully below.

3.4 These results have important implications for public sector pricing. The production efficiency result implies that trades between firms, including those involving public sector firms, should be priced at marginal cost. This provides a clear rationale for the idea that public enterprises should price at marginal cost, at least in their sales to firms, even if the government faces fiscal constraints.

3.5 The commodity tax rules derived by Diamond and Mirrlees relate to the difference between the price consumers pay for the good (the consumer price) and its marginal cost of production. Therefore, if public enterprises did increase the pre-tax price (producer price) of their products there would be no reason for the consumer price to be raised: the nominal tax rate (the difference between the consumer and producer prices) should be reduced to keep the consumer price constant. This implies that, as far as sales to consumers are concerned, the producer price has no allocative role when commodity taxes are optimally set. The role of the producer price in making investment decisions is discussed towards the end of this section, but it can be noted here that setting the producer price equal to marginal cost has the advantage of avoiding the need for the enterprise to price discriminate between firms and consumers: that task can be left to the tax authorities.

3.6 The analysis presumes that any public enterprise profits will accrue as revenue to the government, and that any public enterprise losses will be financed from general revenue. In the context of this model, there is no reason why any particular public enterprise, or the public sector as a whole, should break even. Nonetheless, the widespread use of break-even targets means that it is worth considering the effect of introducing such targets for enterprises that would make a loss when pricing at marginal cost. Such a move would force the affected enterprises to raise their prices above marginal cost. If they only raised their prices to consumers and kept their prices to firms at marginal cost, all that would happen is that the producer price would rise and (continuing to assume optimal taxation) the nominal tax would fall so that the consumer price would be unchanged. The enterprise would have eliminated its loss, but only at the expense of tax receipts. Therefore, there has been no allocative change and the government is no better off than before. On the other hand, if the enterprise raised prices to firms, this would yield some additional revenue to the government but at the cost of distorting production efficiency. The Diamond-Mirrlees result implies that the extra revenue could have been raised more efficiently by increasing the general level of commodity taxes.

3.7 This analysis shows that, under optimal commodity taxation, the imposition of financial targets for enterprises has either no effect or reduces the efficiency of tax collection. However, the assumption of optimal commodity taxation is extremely unrealistic for LDCs and it is best to regard this analysis as a clarification of the basic issues, which is necessary before analyzing the more realistic case of non-optimal taxation.

3.8 Many LDCs raise a very small proportion of their revenue from domestic commodity taxes, often relying heavily on import duties. Import duties that are levied on goods not produced domestically are similar to

commodity taxes but are of limited coverage, and are therefore no substitute for a full domestic commodity tax system. One reason for the lack of comprehensive commodity taxes is the difficulty of administration and it is in this respect that public sector pricing, with its relative ease of administration, is seen as an attractive method of raising revenue.

3.9 With this background, it is probably appropriate to consider the effects of introducing financial constraints on the assumption that the tax system, including any taxes that are levied on the publicly produced goods, will not change in response to any price changes. In this case, the imposition of a break-even constraint on a previously loss-making enterprise will produce an increase in the producer price and the consumer price in sales to consumers. It may also increase the price that the enterprise charges to firms, but the most important issues can be analyzed by concentrating on the sales to consumers.

3.10 The increase in the consumer price is essentially the same as a tax increase because the extra revenue to the firm will be used to reduce the government subsidy, the net effect being a transfer from consumers to the government. The effect of the price increase on government revenue can be divided into two parts: (i) the revenue collected on the good itself; (ii) the effect on revenue elsewhere in the economy. Part (i) is clear enough, and obviously depends partly on the elasticity of demand for the good. Part (ii) arises because consumers will alter their consumption patterns in response to the price change. These changes in consumption patterns will affect the demand for taxed goods and goods produced by other public enterprises that price above marginal cost. These changes in demand will therefore affect government revenue, the magnitude depending on the levels of other taxes and the size of cross-price elasticities.

3.11 In general there is no guarantee that part (ii) of the revenue effect is positive. Also, if there is already a tax on the good in question, part (i) could be negative. It is therefore possible to imagine a situation where the imposition of a break-even target can reduce government revenue. Although it might be argued that such situations are unlikely to arise in practice, they are simply extreme examples of the inefficiency of using financial targets to raise government revenue. In less extreme circumstances, where the total revenue gain from increased prices is positive, it will typically be the case that the ratio of revenue gain to consumer welfare loss will be different for different goods. It is most efficient to increase revenue by raising the prices of goods for which this ratio is highest. The specification of break-even targets, or other financial target, for individual enterprises will only achieve this aim by pure chance. Additional government revenue from public enterprise pricing would be raised more efficiently if some agency of the government compared the costs and benefits of alternative price rises to determine which public enterprises should have the largest differentials between price and marginal cost. These price differentials could then be imposed by setting financial targets, if that was the most appropriate enforcement mechanism or if there were managerial reasons for imposing targets. However, the targets would be different for different enterprises: some might be allowed to make a limited loss, while others may be required to make a substantial profit.

3.12 This argument implies that financial targets should be the consequence of public sector pricing decisions. A result that conflicts with the common practice of using such financial targets to work out what the prices should be.

3.13 The analysis so far has implicitly assumed that each public enterprise produces only one good, so that the imposition of a financial target will determine the single price. If an enterprise produces more than one good, the financial target does not completely constrain the enterprise's pricing choice. It can decide the relative prices of its products. The literature on this choice is summarized in Atkinson and Stiglitz (1980; section 15-2). The standard idea is that the enterprise attempts to meet its financial target at the least cost to consumers. Despite the obvious appeal of this approach, it is not optimal for the economy as a whole because each enterprise will not take account of the effect that its pricing decisions have on the revenue of other firms or on general tax revenue. They will therefore not produce the prices that would have been chosen by a central agency that was concerned with raising a given total of government revenue at least cost to consumers.

3.14 This problem is separate from the issue of the level of the financial targets, and continues to apply even if the financial targets are set optimally. It therefore provides a general argument against the use of financial targets if the enterprises can choose their own prices. However, financial targets can be of great practical importance in providing incentives to enterprises to improve efficiency and enforce the payments of charges. Also, any central agency would have difficulty in obtaining sufficient data to choose the relative prices of the products of multi-product enterprises. The argument against setting any financial target is therefore less persuasive than the main argument of this section: that the financial targets set for an enterprise should be determined by the price it should charge, not the other way round.

B. Fiscal Gains From Pricing Above Marginal Cost

3.15 The discussion above showed that the simple imposition of financial constraints on enterprises is not a good method of improving the fiscal position of the central government. The alternative is to choose public sector prices in a manner which takes account of the full effects of pricing on government revenue. It is therefore necessary, at this point, to look at these revenue effects in more detail. We will concentrate on the case where it is only the price to final consumers that is being raised. The effects of pricing above marginal cost to firms will be considered in more detail later.

3.16 In general, the increase in a public sector price will affect supply and demand throughout the economy and thus alter all prices. It would be a major task to trace out and quantify these effects, and would probably require the construction of a computable general equilibrium model. However, the most important revenue consequences can be analyzed using a simplified model where prices in the rest of the economy are assumed to be unaffected.⁴ In this case, the effects of a public sector price increase are limited to alterations in the pattern of demand.

3.17 If we assume that the profits and losses of public enterprises are simply passed on to the central government (there is no form of profit-sharing within the enterprise), the difference between marginal cost and consumer price has the same effect on government finances and on the

4/ Strictly, this constancy of other prices requires very strong assumptions. The best known set of sufficient conditions are those required for the Non-substitution Theorem: constant returns to scale, one non-produced factor of production and no joint production. The most objectionable of these assumptions is probably that there is only one non-produced factor of production. Heady and Mitra (1982) show how this assumption can be relaxed in the study of commodity taxation, and similar techniques could be used here.

pattern of consumer demand as a tax: the difference is purely administrative. It is therefore convenient to regard them as taxes.

3.18 If there are n goods, the tax revenue of the government minus the losses of public sector enterprises is given by:

$$R = \sum_{i=1}^n t_i X_i - \text{Loss}$$

where R is government revenue available for other uses,

t_i is the tax on good i expressed in absolute (rather than proportionate) terms,

X_i is the total consumer demand for good i ,

Loss is the aggregate net loss of public enterprises excluding the revenue from pricing above marginal cost.

3.19 If we now consider an increase in the price of good 1, this has the effect of increasing the implicit taxation, t , and the consumer price, q , of that good. It should be noted that as "Loss" is worked out on the basis that enterprises only receive their marginal cost, small changes in demand will not affect its magnitude. The derivative of government revenue (net of public sector losses) can therefore be written as:

$$\frac{\delta R}{\delta t_1} = X_1 + t_1 \frac{\delta X_1}{\delta q_1} + \sum_{i=2}^n t_i \frac{\delta X_i}{\delta q_1}$$

where δ is the symbol for partial differentiation.

3.20 The first term in this expression represents the additional revenue that would accrue from a price rise if there was no alteration in the pattern of demand. The second and third terms represent the effects on

revenue that follow from the changes in demand. The second term represents the change in revenue from the existing (explicit or implicit) tax on good 1 that follows from the price increase. This will be negative (unless it is a Giffen good), and could outweigh the first term if either the existing tax was very large and/or the own-price elasticity of demand was large. The sign and magnitude of the third term will depend both on the existing pattern of taxation and the pattern of cross-price elasticities.

3.21 Consideration of this expression should clarify some of the claims made in the analysis of financial constraints. First, if we assume that the third term is zero (demands are independent), it is clear that the revenue raising possibilities of taxes on goods depends on their own-price elasticity of demand, a fact that will not be reflected in the imposition of uniform break-even targets.⁵ Second, if demands are not independent, the non-zero third term indicates that raising prices on one good can affect the revenue elsewhere. This would not be taken into account by an individual enterprise solely concerned with meeting its own financial target.

C. The Distortionary Cost of Pricing Above Marginal Cost

3.22 Government revenue raising usually involves some distortionary cost, and the problem of designing an efficient system of revenue raising involves a minimization of these costs. It is therefore necessary to spell out the distortionary cost of using public sector prices to raise revenue. However, it is worth noting that not all taxes on publicly provided goods are distortionary if an externality is involved in their use. In such a

5/ These differences in revenue raising capability will continue to apply even if the assumption of independent demands is dropped: the differences will just be more difficult to evaluate.

case, there is no conflict between efficiency and revenue raising up to the point where the optimal externality-correcting tax is levied.⁶ The analysis here considers the distortionary costs of raising charges above that level. For reasons of exposition, we start by supposing that only prices to consumers are raised above marginal cost. The distortionary cost of raising prices to firms will be considered afterwards.

3.23 The distortion involved in pricing a publicly produced good above its marginal cost is the same as that generated by a tax: it discourages consumption of that good and encourages consumers to buy other goods which are less efficient (in terms of resources) at meeting the consumers' requirements. This change in consumption patterns is not a cost to the consumer. Indeed, it can be regarded as an attempt by consumers to mitigate their loss from the price increase. However, it is a cost to the government because the shift in consumption is away from the good that is being taxed. The distortionary cost of a public sector price increase is therefore the loss in government revenue that results from the induced change in consumption patterns.

3.24 More formally, the cost to consumers of a small increase in the price of, say, good 1 is the quantity of the good consumed multiplied by the size of the price increase. In other words, the derivative of consumers' costs with respect to the price of good 1 is given by the quantity of good 1 consumed. This can be compared with the expression derived above for the derivative of government revenue, and it can be seen that the difference between the consumers' loss and the government's gain is given by the last two terms, representing the effect of the price change

6/ An important example of such externalities arises in road transport, and Section 4 discusses the level at which road use charges should be set.

on the revenue from existing taxes. Thus the distortionary cost (or "excess burden") of public sector pricing arises from changes in consumption patterns:

Distortionary cost⁷

$$= - \sum_{i=1}^n t_i \cdot \frac{\delta X_i}{\delta q_1}$$

3.25 It will not always be the case that the marginal excess burden of a price change will be positive. It could be negative if there is already a substantial tax on a good that is a substitute for the good whose price is being increased. The reason for this is that the price rise will reduce the distortion in prices between the two substitutes, an effect that might outweigh other distortions produced by raising the price. However, so long as the (more conventional) second measure of excess burden is concerned, the total excess burden (obtained by integrating the marginal distortionary costs) will always be non-negative.

7/ This expression for the marginal distortionary cost of an increase in the price of good 1 is slightly different from the standard one. This is because it is common practice to look not at the cost of a tax increase, but to compare the effect of the distortionary tax increase with that of a lump sum tax that has the same effect on consumer welfare. A lump-sum tax will have income effects on the revenue from existing taxes, and so the extra cost of using public sector pricing is given by the substitution effects alone. Thus, the marginal excess burden of raising the price of good 1 is:

$$- \sum t_i \cdot S_{i1}$$

where S_{i1} is the compensated derivative of demand for good i with respect to the price of good 1.

It should be noted that the choice of which measure to use in comparing alternative price changes will not affect the outcome, as comparisons will typically be between changes that yield similar revenues and have similar effects on consumer welfare. Thus the income effects will be the same and the ordering by one measure will be the same as that by the other.

3.26 Turning now to the issue of the distortions produced by increasing prices to firms above marginal cost, it is necessary to drop the assumption that taxes do not affect prices elsewhere in the economy because a tax on an intermediate good will inevitably alter the prices of either the final outputs or some other inputs. The simplest assumption is to assume that the prices of factors are fixed, that there are constant returns to scale and that all taxes on intermediate goods are shifted forwards onto the final consumer goods. In this case a tax (or price above marginal cost) on an intermediate good will raise the price of the final consumer goods that use it as a direct or indirect input. The rise in the price of each consumer good will equal the rise in the input price multiplied by the share of the input in the cost of producing the consumer good.

3.27 The increase in the price of each consumer good as a result of the input price rise is similar to a direct tax on the consumer good: it raises the price above its social marginal cost and the revenue from it goes to the government (as the revenue from the input price rise). Thus the distortionary effects can be analyzed in just the same way as the consumer price rises above. However, the increase in the price of the intermediate good has another effect: it distorts the choice of technique by firms that use it or goods produced with it. The importance of this distortion depends on the extent of substitution possibilities within production, but the important point to note is that this is an additional distortion which has no corresponding additional revenue gains. It is therefore more efficient to raise revenue by directly taxing the goods produced with the help of the intermediate good than by taxing the intermediate good itself: both policies distort consumer choice, but only the second distorts producer choice. It is this point that lies behind the recommendation of Newbery

(1986) to avoid revenue raising taxation of freight transport unless it is impossible to directly tax the final products.⁸

3.28 This qualification is very important in many countries because of the difficulty of levying commodity taxes on domestically produced consumer goods. There are circumstances where the taxation of intermediate goods (such as freight transport) is desirable in the light of an inability to directly tax the final outputs.⁹ One difficulty of taxing intermediate goods is that it could discourage the taxation of final products, because then they would be subject to double taxation. However, this difficulty could be avoided by allowing firms to claim back the taxes on their inputs if they paid tax on their sales, a system that amounts to a partial Value Added Tax.

3.29 This is unrealistic to assume complete forward shifting of taxes on intermediate goods if some of the final products are internationally traded. Some of the taxation will be passed backwards onto factors, and Hughes (1986) reports on the use of an input-output table to calculate the effects. However, the alternative assumptions used in this case do not alter the basic argument against the taxation of intermediate goods. The new feature of this case is that intermediate good taxation acts like a factor tax as well as a commodity tax, but there is still the additional production distortion. The same tax revenue can be levied more efficiently by implementing the commodity and factor taxes directly, rather than through the taxation of intermediate goods. Thus revenue-raising

8/ The question of whether to tax a particular input into production when there is already production inefficiency due to other input taxes is discussed in Section 4 below.

9/ This problem is analyzed in Feldstein (1972c).

intermediate good taxation is only desirable if direct taxation of its products (or the factors which bear the incidence of the tax) is desirable but administratively infeasible.

D. Distributional Effects of Pricing Above Marginal Cost

3.30 The analysis of the revenue raising and distortionary effects of pricing above marginal cost are sufficient for the design of public sector pricing policy if income distribution is ignored: prices should be raised on those goods with a high ratio of marginal revenue gain to marginal distortionary costs, and lowered for those where that ratio is low. The choice of dividing line between high and low ratios will depend on the government's need for revenue. Prices will be optimal when the ratio of marginal gain to marginal loss is the same for all goods.¹⁰ If demands are independent, this leads to the well-known rule that the ratio of consumer price to producer price (one plus the implicit tax rate) should be inversely proportional to the own-price elasticity of demand.¹¹

3.31 However, public sector products often include goods whose prices are politically sensitive, often for distributional reasons. It is therefore necessary to consider the distributional consequences of pricing above marginal cost.¹²,¹³ First, of course, it is necessary to be able to

10/ This policy leads to "Ramsey pricing", the relation of which to the original paper on taxation, Ramsey (1927), is explained by Bös (1985).

11/ There are in fact two rules here. If it is the compensated demands that are independent, taxes (or the proportional mark-up of price over marginal cost) should be inversely proportional to the compensated elasticities of demand. If it is the uncompensated (Marshallian) demands that are independent, taxes should be inversely proportional to the uncompensated elasticities of demand.

12/ This problem was first analyzed by Feldstein (1972a).

13/ We will ignore here the attempts that are sometimes used to ameliorate the distributional effects of high prices by using a differential price system that benefits poorer consumers.

describe the distributional effects of price increases. This is straight forward for prices to consumers provided there is some data on consumption patterns at different income levels. The distributional effects of prices to firms would require the techniques referred to above in order to predict their effect on consumer goods and factor prices.

3.32 Once the distributional effect of the price increase has been described, the situation is no longer one of balancing a revenue gain against an homogeneous consumer loss. Instead, the loss involves a series of losses to households at different points in the income distribution. A concern for income distribution implies that more weight should be applied to losses that fall on low income households. Thus the cost of the revenue equals the weighted sum of individual household losses, where the weights decline with household income. It is then the ratio of the revenue gain to this weighted loss that should determine whether a public sector price should be raised or lowered.¹⁴

3.33 This use of distributional weights can also deal with situations where the public sector is selling output to foreigners, as is often the case with ports. The weight put on losses to foreigners could well be zero, unless there was some special reason for taking account of their welfare.

E. The Choice Between Taxes and Higher Prices for Enterprises

3.34 In discussing the question of pricing to consumers, the question of whether it is raised by using a tax or by increasing the producer price that the firm receives has been regarded as an administrative issue. This is because we have been mainly concerned with the effects on consumer demand and government revenue. However, the increase in a price also

14/ This is the technique used by Ahmad and Stern (1987) in comparing alternative sources of tax revenue.

affects the enterprises producing goods and it is to that issue that the analysis now turns. In particular, should the price to the consumer be raised by increasing the producer price so that the firm's profits rise, or should it be raised by a tax so that the firm's profits are unaffected and the money goes straight to the central government?

3.35 To a certain extent, the answer to this question is the administrative one of which is the easier system to operate and which is less likely to suffer from fraud. There is also the potential problem of firms spending some of their increased profitability on higher wages or fringe benefits. These issues depend on administrative arrangements and are outside the scope of this paper. The interest here is in the effect of the alternative systems on output and investment decisions.

3.36 With a given capital stock, output will be the same under the two systems because they produce the same wedge between marginal cost and consumer price. Marginal cost depends only on output in the short run, and so output is determined at the level where the inflated marginal cost curve intersects the market demand curve. In other words, the pricing rule determines output.

3.37 However, investment might reduce marginal costs and so provides the enterprise with some freedom. If pricing is based on short-run marginal cost (plus a revenue raising mark-up), new investment will lower the price and increase output. This will be more attractive to the firm if the price increase was in the form of a high producer price than if it was in the form of taxation.¹⁵

^{15/} On the one hand, if pricing was based on long-run marginal cost, investment would have little if any effect on price, and hence demand and profit. However, Section 1 came to the conclusion that short-run marginal cost should form at least part of the pricing rule and so this exception should have little practical importance.

3.38 The extra investment encouraged by raising producer prices under short-run marginal cost pricing is undesirable because it represents an attempt to undercut the price that was set by comparing the costs and benefits of alternative price changes. Thus, although it raises additional profits for the enterprise concerned, it will be harming the revenue raising abilities of other taxes and public enterprises. In this case, it is therefore better to use taxes, or else to have government control of investment decisions in order to prevent excessive investment.

F. Data Requirements

3.39 In considering the data requirements for calculating how far public sector prices should differ from marginal cost, it is easiest to think first about the requirements for the simplest adjustments and then consider the additional data for more complex cases.

3.40 The simplest case is when it is only sales to consumers that will be priced above marginal cost, and there is no concern for the effect of pricing on the distribution of income. The distortionary cost estimates require information on taxes (and the extent of pricing above marginal cost in public enterprises) and estimates of a demand system, in order to predict the effect of price changes on the revenue from existing taxes.

3.41 It is tempting to assume independent demands (either compensated or uncompensated) because of the reduction in the number of parameters that have to be estimated. However, it is impossible for all compensated demands to be independent (the theoretical tax literature usually assumes the existence of an untaxed good which absorbs all the substitution effects), and uncompensated demands can only all be independent if all the own-price elasticities of demand are unity. Also, it is clear that substitution between different goods within a category (fuel or transport) can have important revenue effects. At the very least, it is possible to use an own-

price elasticity (together with the budget constraint) to work out the effect of a price change on the total demand for all other goods and then to multiply that effect by the average tax rate on all other goods to obtain an approximate revenue effect from substitution into other goods. In many cases it will be possible to do better than this and obtain estimates (perhaps from other countries) of how the increased expenditure on all other goods will be divided between important categories of goods.

3.42 Moving to the pricing of sales to firms, an analysis of the fiscal and distortionary effects requires the use of the technique described by Newbery and mentioned above to calculate the effects of intermediate good prices on factor and consumer goods prices. This technique requires an input-output table and a knowledge of which goods are internationally traded. This technique allows the calculation of the effects on factor price and consumer prices, and their fiscal and distortionary effects can be calculated using the data discussed above. However, the pricing of intermediate goods above marginal cost also has a distortionary effect on production (measured as the revenue lost by substitution away from taxed inputs), which can only be estimated with some knowledge of substitution possibilities in the relevant industries. This may well be the most difficult data to obtain.

3.43 The introduction of distributional considerations is the final complication to be introduced. This requires a household budget survey in order to allocate the losses from price increases between households on different income levels. The distributional weights are the other requirement, but these come from the government's objectives rather than empirical data.

SECTION 4: METERING PROBLEMS

4.1 The analysis in the paper so far has assumed that the consumption of goods can be observed, so that charges can be made for them. As the time at which goods are consumed is sometimes of considerable economic significance (for example, road use at peak times has different costs from road use at off-peak times), this assumption implies that, for those goods, the timing of consumption can also be observed and included in the charging formula. Similarly, location of road use (rural versus urban, for example) can be important and different charges should be made for the use of different roads. In practice, it is difficult to undertake all the observations required to implement such optimal policies and so pricing policy must reflect the metering difficulties involved.

4.2 This section considers how pricing policy should be adapted to take account of metering difficulties. In order to bring the discussion into focus, the analysis will be conducted in terms of the specific metering problems involved in levying road user charges. However, the principles involved will be the same for other goods with metering problems.

4.3 The discussion in this section will be kept at an intuitive level, while the formal derivations of results are shown in the appendix. The formal models disregard revenue-raising considerations in order to clarify the implications of metering problems. However, the discussion of these results in this section will include considerations of revenue where appropriate.

4.4 In the absence of metering difficulties, road users should be charged for the externalities involved in additional road use: damage to the road, pollution and extra congestion. Model 1 in the appendix shows

that the charges for road use should equal the marginal external costs. However, it is often impractical to make such charges, for reasons discussed below, and other approaches must be used.

4.5 The discussion will center around two related but distinct aspects of metering difficulties. The first is the difficulty of taxing different road uses at different rates. The second is the possible need to charge for road use indirectly, via taxes on inputs such as fuel.

A. Charging for Different Uses

4.6 Walters (1968) argued for the charging of different road uses at different rates because of differences in the marginal cost, particularly congestion costs, of road use in different locations and at different times. However, this recommendation has not been widely implemented. One of the reasons for this is the practical difficulty of measuring each vehicle's use of different types of road at different times of day. In part, this difficulty arises from the costs of measuring total road use directly, so that charges are often made indirectly on the more easily measurable inputs such as fuel. The issues that arise from indirect charging are addressed more fully below, but in the current context it is clear that a fuel tax cannot discriminate between the use of different roads at different times of day. However, even if total road use could be measured reliably, there would remain the problem of charging separately for different uses. Time of day could be incorporated relatively easily into a tachometer based system, but the metering of which roads are used involves more severe technical difficulties and can be perceived as an invasion of personal privacy.

4.7 In these circumstances, it is necessary to consider how to set road use charges if they are constrained to be uniform across time and location. Model 4 in the appendix addresses this issue by considering the

case where two different uses must be taxed at the same rate. The analysis can readily be generalized to more than two uses.

4.8 The essence of the situation is that the raising of the uniform tax on all road uses will reduce each type of road use by an amount dependant on the demand elasticity for that type of road use. The demand elasticities are outside the control of the government, which is therefore unable to control the relative size of the reductions. This means that the government can only control a weighted average of the road uses, where the weights depend on consumer preferences. It therefore sets the road use charge at a weighted average of the road use costs from each type of road use. The appendix shows that the correct weights in this average are the compensated derivatives of each road use with respect to the uniform tax.

4.9 This result is quite intuitive and implies that some road uses will be over-charged, while others are undercharged. This means that the constrained pricing leaves some externalities that have not been fully internalized. This means that one should consider the effects of other prices on the harm caused by the externalities. Thus, any good which is more of a substitute for the under-taxed road uses than over-taxed uses should have its price reduced to discourage those uses. Similarly, any good that is more of a substitute for over-taxed uses should have its price increased. This rule would be very hard to apply for all goods because of data limitations, but it might be possible to establish whether public transport is more of a substitute for (under-taxed) peak traffic than for (over-taxed) off-peak traffic.

4.10 The introduction of fiscal considerations does little to alter the situation. From the point of view of the tax authorities, the road uses can be viewed as one aggregate good and the fiscal adjustment to the charge derived in the appendix can be determined using the techniques described in

Section 3. However, it must be remembered that much of road use involves freight, which is an intermediate good, and thus requires more complicated procedures for the evaluation of both fiscal and distortionary effects. The taxation of personal private transport, on the other hand, can be analyzed in the same way as any consumption good.

B. The Use of Indirect Charges

4.11 As explained above, the difficulties of directly measuring road use often induce governments to tax it indirectly through inputs such as fuel. This has the effect of making it more difficult to tax different uses at different rates, an issue addressed above. Indirect charging also has other effects, and it is to these that we now turn.

4.12 Model 2 in the appendix analyses the case where only the privately purchased inputs into road use can be taxed, and shows that the optimal policy is to tax all inputs at a uniform proportional rate. This has the same effect as the same proportional tax on road use itself. Therefore, in the context of the model, there is nothing lost by the use of indirect charging.

4.13 It is important to note that the taxation of inputs into road use (such as diesel) in accordance with the results of Model 2 does not contradict the argument against input taxation, explained in Section 3. The reason for this is that the argument of Section 3 was in terms of preventing the distortion of production activities. But the taxes obtained in Model 2 are not distortionary; they are corrective and their application will therefore improve production efficiency.

4.14 A further point in connection with production efficiency is that it is only achieved if all inputs are free of distortionary taxation. If some other inputs are already taxed (by sales taxes, excise duties or

import duties¹⁶), it may be best to impose taxes on inputs into road use, in addition to the corrective taxes. Model 5 in the appendix derives a formula for this additional taxation, which is a variant of the weighted average formula derived by Dixit and Newbery (1985) in the case where there is no road user cost. The formal derivation in the appendix is conducted in terms of charging for inputs into personal transport, but the argument applies equally well to the derived demand for transport by firms. The formula allows a decomposition of the overall tax into a road use cost component and a component that partially corrects for other distortions in the economy.

4.15 The uniform taxation result of Model 2 should be interpreted with care even if there is no reason to apply the extra tax component for distortionary taxation of other goods. It assumes that all inputs can be taxed and it assumes that the taxes do not apply to non-transport uses of the input. The first assumption would be violated for personal transport (and perhaps small-scale commercial transport) as the input of labor cannot usually be taxed. The second assumption is also violated by the non-transport uses of diesel, which cannot effectively be taxed at a lower rate than transport uses because of the difficulty of preventing resale between sectors. This point is discussed by Newbery (1986).

16/ Import duties should be included in the definition of taxes even if the duties are used to protect domestic industries, such as vehicle assembly. The reason for this is that import duties are equivalent to a sales tax and a production subsidy. It is the production subsidy that is protecting domestic industry, while the sale tax is discouraging consumption.

4.16 The case where one of the inputs cannot be taxed is analyzed in the Model 3 in the appendix. The tax rate on the remaining good¹⁷ will then depend partly on the extent to which it can influence the consumption of the untaxed input. If it has no (compensated) effect, the tax on the remaining good is simply the value of its marginal contribution to road use costs. If it reduces the consumption of the other good, because the reduction in road use outweighs any substitution between the inputs, the tax rate will be higher to reflect this extra beneficial effect. If the two goods are used in fixed proportions, the tax rate on the taxed good will be increased to incorporate the entire tax that should have been paid on the untaxed good. In this case, the restriction on taxation has no harmful effect: in essence, a tax on any input can be used to discourage road use without any distortions caused by input substitution.

4.17 In general, one would expect there to be some substitution between inputs so that the non-taxability of an input will reduce the overall charge on road use and leave some of the road use externality uncorrected.

4.18 Turning to the second assumption that might be violated, the existence of "by-product" distortions caused by the non-transport use of taxed inputs will lower the optimal tax on the input concerned. The extent by which it should be lowered will depend on the marginal cost of the distortions, represented by the losses of government revenue plus the harm of any adverse changes in income distribution (or minus the benefit of favorable changes). This case is not explicitly modelled in the appendix, but its effect on road use charging will be similar to that of a non-taxable input because it prevents the good from making its full

17/ This result would apply to each of the remaining inputs if there were more than one.

contribution to the discouragement of road use.¹⁸ Therefore, as above, the taxes on other inputs will depend on the extent that they are substitutes with the input whose tax is constrained. Also, as above, there will be an externality that is not fully internalized and, if possible, the pricing on other goods should be adjusted to reduce the harm of this distortion.

4.19 The introduction of fiscal considerations with indirect charges introduces no new issues of principle, even if the charges are restricted. However, it must be noted that many inputs into transport are also inputs into other production processes, and so the evaluation of both fiscal and distortionary costs are made more complicated.

C. Data Requirements

4.20 The fundamental data requirement for setting road user charges are the marginal road user cost for different vehicles at different places at different times. The introduction of metering problems, however, requires data on the demand characteristics of both road use and its inputs. The need for uniform charging requires data on the compensated demand responses to changes in the charge, while restrictions on indirect charging require data on the complementarity between different inputs into road use. In addition, the consideration of distortionary taxes elsewhere in the economy requires data on the compensated demand responses of taxed goods to changes in road use charges.

4.21 It must be remembered that much of the demand for road use, and other taxed goods, come from firms. The effects of charges on their derived demands for inputs are therefore as important as the effects of charges on direct consumer demand.

18/ A similar case arises if, as suggested by Newbery (1986), it is thought unwise to tax tires and spare parts heavily because of the adverse effects on safety.

SECTION 5: SUMMARY AND CONCLUSIONS

5.1 This paper has addressed a number of issues connected with the setting of public sector prices, paying particular attention to the government's need to raise revenue and the special problems of charging in the transport sector. Conclusions have been derived for the choice of marginal cost concept, for the setting of revenue raising prices and for the design of pricing in the presence of metering difficulties.

5.2 In considering the choice between long-run and short-run marginal cost as a basis for pricing, it was shown that the argument for short-run marginal cost pricing depended on the ability to alter prices when there are changes in capacity utilization. It is therefore most appropriate in industries where excess capacity will last for an appreciable time. The argument for long-run marginal cost pricing centered on the need for certainty about future prices to guide investment decisions and therefore applied to cases where incorrect investment decisions would be very costly. It would be possible to use a weighted average of long and short-run marginal cost with the weights chosen in each industry to reflect the relative importance of the various factors.

5.3 In considering the relationship between investment policy and pricing, it was shown that differences only occur when there are indivisibilities in investment. Short-run marginal cost pricing produces a more efficient use of investment, but it is impossible to say which pricing rule will generate earlier increases in capacity.

5.4 The consideration of the fiscal role of public sector pricing was the major concern of the paper. It was shown that the use of financial targets for enterprises produced pricing decisions that did not raise revenue efficiently - in extreme cases they could even reduce revenue. It

was therefore argued that prices should be set on the basis of their economy wide effect and financial constraints, if any, should only be imposed in the light of the prices set. This constitutes a reversal of a common situation, where financial constraints are imposed first and prices set in response to those constraints. The final conclusion in relation to financial constraints was that, even if they are set in response to the desirable level of prices, the enterprises will still not have an incentive to set the correct structure of prices if they produce more than one good.

5.5 The remaining results on revenue raising consist of recommendations as to how prices should be set by taking account of their revenue raising effect, their distortionary effect and their distributional effect. It was shown that the prices of intermediate goods should only be set above marginal cost if it was administratively impractical to levy taxes on the goods for which they are inputs. The pricing of consumer goods should depend on both the own-price elasticity of demand and the cross-price elasticities, while consideration of income distribution requires a weighting of the losses that fall on households at different income levels. As a special case, if there are no distributional effects and if cross-elasticities of demand are zero, the proportionate mark-up of price over marginal cost should be inversely proportional to the own-price elasticity of demand.

5.6 A consideration of investment behavior showed how enterprises that based their prices on short-run marginal cost might be encouraged to over invest in new capacity if they received the higher prices that are required to raise revenue. In this case, it would be better for the government to raise the consumer price through taxes rather than higher producer prices.

5.7 Finally, the paper turned to metering problems that might affect the ability to charge the theoretically optimal prices. The analysis concentrated on road use charges, and it was shown that if different uses had to be charged at the same rate the optimal rate is a weighted average of the marginal costs of each use, with the weights being equal to the compensated derivatives of demand for each use with respect to the charge. The case of indirect charging was also considered. Here it was shown that the optimal policy was to tax all inputs at a uniform proportional rate. However, if some inputs could not be taxed at all, or their taxation was limited by concern for "by-product" distortions, the taxes on other inputs should be raised to the extent that such taxes discourage the use of the untaxed (or under-taxed) input. The influence on charging policy of distortions elsewhere in the economy were also analyzed.

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APPENDIX

THE DESIGN OF ROAD USER CHARGES

The purpose of this appendix is to present a formal analysis of road user charges to justify the statements made in the main text of the paper. The analysis is conducted using models that are as simple as possible, given the problem to be analyzed. Thus the analysis is in terms of a single consumer economy (or a large number of identical consumers) where there are fixed producer prices. It is assumed that the road user cost bears entirely on the production sector and that the government is able to raise revenue through lump-sum taxation. The last assumption is used to avoid the revenue raising issues that are dealt with extensively in the main body of the paper. The taxes derived here are therefore those that are justified on purely allocative grounds. The taxes higher than those derived here would have to be justified in terms of the revenue raising arguments discussed in the paper.

The analysis is conducted through a series of models with different assumptions about the government's tax powers. The first assumes that the road user cost does not vary by time of day (or week, month or year) or location (urban, inter-urban or rural) and that the government can directly tax road use. It can also be regarded as applying to the setting of road user charges for a particular time period (peak or off-peak for example) in a particular location, provided that this rate can be set independently from those at other times or places. This is a particularly simple case, but serves as a useful benchmark.

The second model is the same as the first except that road use can no longer be taxed directly, but can only be charged for by taxing its inputs. The third model is the same as the second, but it is assumed that one of the inputs cannot be taxed. The fourth model returns to the direct taxation of road use, but assumes that the same charge must be made at different times and/or locations. Finally, the fifth model addresses the question of how these tax policies should be adjusted to take account of the existence of other taxes in the economy.

Model 1: The Model With Direct Taxation of Road Use

The level of road use is denoted by X and the consumption of other goods is denoted by Z . Road use reduces the productive capability of the economy by an amount $C(X)$, where $C(\cdot)$ is a convex function. Road use involves the consumer in purchasing two inputs, R and S , and the technology is such that:

$$X = F(R, S)$$

where $F(\cdot, \cdot)$ is the road use production function.

If the goods R , S , and Z are measured in units that cost equal amounts to produce, the production constraint can be written as:

$$R + S + Z = P - C(X)$$

where P is the productive capacity of the economy.

If road use is charged at rate t , the consumer's budget constraint can be written as:

$$R + S + Z + t.X = Y$$

where Y is the consumer's income.

The consumer is assumed to maximize utility subject to the budget constraint, and the solution can be expressed as an indirect utility function $V(t, Y)$. The government can control Y through lump-sum taxation and so its problem is to:

maximize: $V(t, Y)$

subject to: $R(t, Y) + S(t, Y) + Z(t, Y) = P - C(X)$

The consumer's budget constraint that lies behind the demand functions for R, S and Z implies that the government's budget constraint is satisfied whenever the production constraint is satisfied. There is therefore no need to include the government's budget constraint explicitly. The lagrangean for this problem is:

$$L = V(t, Y) + \theta \cdot (P - C(X) - R(t, Y) - S(t, Y) - Z(t, Y))$$

The first-order conditions for a maximum are:

$$\frac{\delta L}{\delta t} = \frac{\delta V}{\delta t} - \theta \cdot \left[\frac{dC}{dX} \left(\frac{\delta F}{\delta R} \frac{\delta R}{\delta t} + \frac{\delta F}{\delta S} \frac{\delta S}{\delta t} \right) + \frac{\delta R}{\delta t} + \frac{\delta S}{\delta t} + \frac{\delta Z}{\delta t} \right] = 0$$

$$\frac{\delta L}{\delta Y} = \frac{\delta V}{\delta Y} - \theta \cdot \left[\frac{dC}{dX} \left(\frac{\delta F}{\delta R} \frac{\delta R}{\delta Y} + \frac{\delta F}{\delta S} \frac{\delta S}{\delta Y} \right) + \frac{\delta R}{\delta Y} + \frac{\delta S}{\delta Y} + \frac{\delta Z}{\delta Y} \right] = 0$$

Differentiation of the consumer's budget constraint with respect to t and Y, respectively gives:

$$\frac{\delta R}{\delta t} + \frac{\delta S}{\delta t} + \frac{\delta Z}{\delta t} + t \cdot \left(\frac{\delta F}{\delta R} \frac{\delta R}{\delta t} + \frac{\delta F}{\delta S} \frac{\delta S}{\delta t} \right) + X = 0$$

$$\frac{\delta R}{\delta Y} + \frac{\delta S}{\delta Y} + \frac{\delta Z}{\delta Y} + t \cdot \left(\frac{\delta F}{\delta R} \frac{\delta R}{\delta Y} + \frac{\delta F}{\delta S} \frac{\delta S}{\delta Y} \right) = 1$$

Substitution of these expressions into the first-order conditions produces:

$$\frac{\delta L}{\delta t} = -\alpha \cdot X - \theta \cdot \left[\left(\frac{dC}{dX} - t \right) \cdot \left(\frac{\delta F}{\delta R} \frac{\delta R}{\delta t} + \frac{\delta F}{\delta S} \frac{\delta S}{\delta t} \right) - X \right] = 0$$

$$\frac{\delta L}{\delta Y} = \alpha - \theta \cdot \left[\left(\frac{dC}{dX} - t \right) \cdot \left(\frac{\delta F}{\delta R} \frac{\delta R}{\delta Y} + \frac{\delta F}{\delta S} \frac{\delta S}{\delta Y} \right) + 1 \right] = 0$$

where $\alpha = \frac{\delta V}{\delta Y}$, the marginal utility of income.

It is clear that one solution to these first-order conditions is that $\alpha = 0$ and t is set equal to the marginal cost of road use (excluding the private costs of buying R and S). It is, in fact, the only solution to these equations unless the two expressions of partial derivatives bear a very special relationship to each other.¹⁹

This result, that externalities should be corrected by a tax equal to their marginal cost, is of course well known as Pigouvian taxation. However, it forms a useful benchmark with which to compare the results of the other models.

Model 2: The Model With Input Taxation

This model is the same as the first except that direct taxation of road use is not possible. Instead, there are taxes on the two inputs into road transport, R and S , at rates t_R and t_S respectively. The consumer's budget constraint therefore becomes:

$$(1 + t_R).R + (1 + t_S).S + Z = Y$$

The production constraint is the same as before, and so is the lagrangean except that there are now two taxes so that indirect utility is written as $V(t_R, t_S, Y)$. The first-order conditions are therefore the same, except that there is one for each tax rate. However, the results of differentiating the budget constraint with respect to t_R , t_S and Y are:

19/ The relationship would imply that the substitution effects in the demands for R and S have no effect on road use. In such a case, only income effects can alter road use and the lump-sum becomes just as effective as a tax on road use.

$$R + (1 + t_R) \cdot \frac{\delta R}{\delta t_R} + (1 + t_S) \cdot \frac{\delta S}{\delta t_R} + \frac{\delta Z}{\delta t_R} = 0$$

$$(1 + t_R) \cdot \frac{\delta R}{\delta t_S} + S + (1 + t_S) \cdot \frac{\delta S}{\delta t_S} + \frac{\delta Z}{\delta t_S} = 0$$

$$(1 + t_R) \cdot \frac{\delta R}{\delta Y} + (1 + t_S) \cdot \frac{\delta S}{\delta Y} + \frac{\delta Z}{\delta Y} = 1$$

Substitution of these expressions into the first-order conditions produces:

$$\frac{\delta L}{\delta t_R} = -\alpha \cdot R - \theta \cdot \left[\frac{\delta R}{\delta t_R} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta t_R} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - t_S \right) - R \right] = 0$$

$$\frac{\delta L}{\delta t_S} = -\alpha \cdot S - \theta \cdot \left[\frac{\delta R}{\delta t_S} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta t_S} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - t_S \right) - S \right] = 0$$

$$\frac{\delta L}{\delta Y} = \alpha - \theta \cdot \left[\frac{\delta R}{\delta Y} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta Y} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - t_S \right) + 1 \right] = 0$$

As in the previous model, there is a clear solution to these equations involving $\alpha = \theta$. Each of the two tax rates are set equal to the other term in the bracket. Thus the tax on R, for example, is equal to the road user cost of the extra road use produced by one extra unit of R.

This result is quite intuitive but is made more interesting by further consideration. A utility maximizing consumer will choose R and S to minimize the private cost of road use, and will therefore choose them so that their consumer prices are proportional to their marginal products. But the taxes derived above are also proportional to the marginal products, and so the taxes will be proportional to prices. In other words, the inputs

into road use should be taxed at a uniform percentage rate. However, an equal proportional tax on the inputs of an activity is equivalent to the same proportional tax on its output. The tax on inputs will therefore have the same effect as the direct tax on road use, although input taxes cannot be so well targeted for time of day or location.

Model 3: The Model With Partial Input Taxation

This model is the same as the one above except that only one of the inputs can be taxed. This might arise through the administrative difficulty of taxing particular inputs, such as household labor, or because the input is used elsewhere in the economy where it is undesirable for it to be taxed.²⁰

Suppose that S is the good that cannot be taxed. This affects the first-order conditions above by eliminating the first-order condition for t_S and setting the value of t_S equal to zero elsewhere. The conditions therefore become:

$$\frac{\delta L}{\delta t_R} = -\alpha \cdot R - \theta \cdot \left[\frac{\delta R}{\delta t_R} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta t_R} \cdot \frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - R \right] = 0$$

$$\frac{\delta L}{\delta Y} = \alpha - \theta \cdot \left[\frac{\delta R}{\delta Y} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta Y} \cdot \frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - 1 \right] = 0$$

If we add R times the second condition to the first and use the Slutsky equation, we obtain:

$$S_{RR} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + S_{SR} \cdot \frac{dC}{dX} \cdot \frac{\delta F}{\delta S} = 0$$

20/ For example, Newbery (1986) cites the non-transport uses of diesel and its close substitute, kerosene, as a reason for not taxing diesel as heavily as one would wish to otherwise.

where S_{RR} and S_{SR} are the substitution effects of the price of R on the demands for R and S respectively.

Therefore:

$$t_R = \frac{dC}{dX} \cdot \left(\frac{\delta F}{\delta R} + \frac{\delta F}{\delta S} \cdot [S_{SR}/S_{RR}] \right)$$

This expression for the optimal tax on the taxable input is somewhat more difficult to interpret than the previous results. This is no doubt due to the fact that a genuine restriction on government action has been introduced. It is easiest to proceed by considering first the special case where S_{SR} is zero, so the tax on R has no substitution effect on demand for S. This means that the only advantage taxation of R has over lump-sum taxation is the reduction in demand for R itself. Thus the tax is simply given by the product of the marginal product of R and the marginal road user cost.

As S_{RR} is negative, a positive value for S_{SR} would imply a lower rate of tax than for the special case. The reason for this is that taxation of R will promote the use of S and thus partially offset the effect of the reduction in R on road use. However, this case is unlikely as it involves substitution in production between R and S that is high enough to outweigh the disincentive on road use. It is more likely that S_{SR} is negative, implying that the use of inputs decline together. This would have the effect of raising t_R . But t_R would only rise enough to embody all of the tax that should have been on S if the ratio between the substitution effects equals the ratio of their demands - implying fixed coefficients in production between S and R.

Model 4: The Model With Different Uses Charged at the Same Rate

In this model we analyze the effect of recognizing that it is often impossible to charge different road uses at different rates. In order to keep the analysis simple, it is assumed that the charge can be levied directly. We also dispense with the analysis of purchased inputs into road use and assume instead that road use is a good that can be purchased directly.²¹

There are two road uses, X_1 and X_2 , which are taxed at a uniform rate. The budget constraint is therefore:

$$(1 + t) \cdot X_1 + (1 + t) \cdot X_2 + Z = Y$$

The production constraint is:

$$X_1 + X_2 + Z = P - C(X_1, X_2)$$

where $C(.,.)$ is the cost function of road use, generalized to take account of the different costs of different uses.

The lagrangean for the problem is now:

$$L = V(t) - \theta \cdot [X_1 + X_2 + Z + C(X_1, X_2)]$$

The first-order conditions for a maximum are:

$$\frac{\delta L}{\delta t} = -\alpha \cdot (X_1 + X_2) - \theta \cdot \left[\frac{\delta X_1}{\delta t} \cdot \left(1 + \frac{\delta C}{\delta X_1}\right) + \frac{\delta X_2}{\delta t} \cdot \left(1 + \frac{\delta C}{\delta X_2}\right) + \frac{\delta Z}{\delta t} \right] = 0$$

$$\frac{\delta L}{\delta Y} = \alpha - \theta \cdot \left[\frac{\delta X_1}{\delta Y} \cdot \left(1 + \frac{\delta C}{\delta X_1}\right) + \frac{\delta X_2}{\delta Y} \cdot \left(1 + \frac{\delta C}{\delta X_2}\right) + \frac{\delta Z}{\delta Y} \right] = 0$$

Differentiation of the budget constraint with respect to t and Y respectively produce:

21/ This is effectively the same as assuming that the production function $F(.,.)$ is constant returns and that input prices are fixed.

$$X_1 + X_2 + (1 + t) \cdot \left(\frac{\delta X_1}{\delta t} + \frac{\delta X_2}{\delta t} \right) + \frac{\delta Z}{\delta t} = 0$$

$$(1 + t) \cdot \left(\frac{\delta X_1}{\delta Y} + \frac{\delta X_2}{\delta Y} \right) + \frac{\delta Z}{\delta Y} = 1$$

Substituting these terms into the first-order conditions produces:

$$\frac{\delta L}{\delta Y} = -\alpha \cdot (X_1 + X_2) - \theta \cdot \left[\frac{\delta C}{\delta X_1} \cdot \frac{\delta X_1}{\delta t} + \frac{\delta C}{\delta X_2} \cdot \frac{\delta X_2}{\delta t} - X_1 - X_2 - t \cdot \left(\frac{\delta X_1}{\delta t} + \frac{\delta X_2}{\delta t} \right) \right] = 0$$

$$\frac{\delta L}{\delta Y} = \alpha - \theta \cdot \left[\frac{\delta C}{\delta X_1} \cdot \frac{\delta X_1}{\delta Y} + \frac{\delta C}{\delta X_2} \cdot \frac{\delta X_2}{\delta Y} + 1 - t \cdot \left(\frac{\delta X_1}{\delta Y} + \frac{\delta X_2}{\delta Y} \right) \right] = 0$$

Adding $(X_1 + X_2)$ times the second condition to the first, and using the Slutsky equation, we obtain:

$$S_{1t} \cdot \frac{\delta C}{\delta X_1} + S_{2t} \cdot \frac{\delta C}{\delta X_2} = t \cdot (S_{1t} + S_{2t})$$

where S_{1t} and S_{2t} are the compensated derivatives of the demand for X_1 and X_2 respectively.

Therefore:

$$t = \left(S_{1t} \cdot \frac{\delta C}{\delta X_1} + S_{2t} \cdot \frac{\delta C}{\delta X_2} \right) / (S_{1t} + S_{2t})$$

This tax rule says that the tax on the two road uses should be a weighted average of the two marginal road use costs, with the weights being the compensated effect of tax changes on the demand for each road use.

Model 5: The Effect of Taxes Elsewhere in the Economy

The models considered so far in this appendix have assumed that there are no taxes elsewhere in the economy. The purpose of this model is to consider how the existence of other taxes affect the tax rules we have derived.

The model used here is an extension of model 2, where road user charges are collected through input taxes. It is extended by considering a range of non-transport goods, $Z_1, \dots, Z_1, \dots, Z_n$ each of which is taxed at a rate t_i . The consumer's budget constraint now becomes:

$$(1+t_R).R + (1+t_S).S + \Sigma(1+t_i).Z_i = Y$$

where the summation, Σ , runs over all i ($= 1, \dots, n$) unless otherwise stated.

The economy's production constraint becomes:

$$R + S + \Sigma Z_i = P - C(X)$$

The first-order conditions for the choice of t_R , t_S and Y are the same as before except that differentials of Z are replaced by the sum of the differentials of Z_i . The results of differentiating the budget constraints are now:

$$R + (1 + t_R) \cdot \frac{\delta R}{\delta t_R} + (1 + t_S) \cdot \frac{\delta S}{\delta t_R} + \Sigma(1 + t_i) \cdot \frac{\delta Z_i}{\delta t_R} = 0$$

$$(1 + t_R) \cdot \frac{\delta R}{\delta t_S} + S + (1 + t_S) \cdot \frac{\delta S}{\delta t_S} + \Sigma(1 + t_i) \cdot \frac{\delta Z_i}{\delta t_S} = 0$$

$$(1 + t_R) \cdot \frac{\delta R}{\delta Y} + (1 + t_S) \cdot \frac{\delta S}{\delta Y} + \Sigma(1 + t_i) \cdot \frac{\delta Z_i}{\delta Y} = 1$$

Substitution of these expressions into the first-order conditions produces:

$$\frac{\delta L}{\delta t_R} = -\alpha \cdot R - \theta \cdot \left[\frac{\delta R}{\delta t_R} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta t_R} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - t_S \right) - \Sigma t_i \cdot \frac{\delta Z_i}{\delta t_R} - R \right] = 0$$

$$\frac{\delta L}{\delta t_S} = -\alpha \cdot S - \theta \cdot \left[\frac{\delta R}{\delta t_S} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta t_S} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - t_S \right) - \Sigma t_i \cdot \frac{\delta Z_i}{\delta t_S} - R \right] = 0$$

$$\frac{\delta L}{\delta Y} = \alpha - \theta \cdot \left[\frac{\delta R}{\delta Y} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta R} - t_R \right) + \frac{\delta S}{\delta Y} \cdot \left(\frac{dC}{dX} \cdot \frac{\delta F}{\delta S} - t_S \right) - \sum t_i \cdot \frac{\delta Z_i}{\delta Y} + 1 \right] = 0$$

The addition of R times the last equation to the first equation produces:²²

$$S_{RR} \cdot (C_R - t_R) + S_{SR} \cdot (C_S - t_S) - \sum S_{iR} \cdot t_i = 0 \quad (A.1)$$

where C_R and C_S denote the marginal effect of R and S respectively on the value of $C(X)$;

S_{iR} denotes the substitution effect of the price of R on the demand for Z_i .

This equation can be written as:

$$t_R - C_R = -[S_{SR} \cdot (t_S - C_S) + \sum t_i \cdot S_{iR}] / S_{RR} \quad (A.2)$$

However, cost-minimization by the consumer implies:

$$(1 + t_R) \cdot S_{RR} + (1 + t_S) \cdot S_{SR} + \sum (1 + t_i) \cdot S_{iR} = 0$$

The addition of (A.1) to this equation produces:

$$S_{RR} \cdot (1 + C_R) + S_{SR} \cdot (1 + C_S) + \sum S_{iR} = 0$$

This enables us to substitute for S_{RR} in (A.2):

$$[t_R - C_R] / (1 + C_R) = [S_{SR} \cdot (t_S - C_S) + \sum t_i \cdot S_{iR}] / [S_{SR} \cdot (1 + C_S) + \sum S_{iR}]$$

22/ A similar equation can be obtained from the second equation.

It is this equation that allows us to see how the existence of taxes elsewhere in the economy should affect the taxation of inputs into road use.

This equation for the optimal tax on R is most easily interpreted if we begin by neglecting the road user cost element, so that C_R and C_S are zero. In this case, the equation simply requires that the tax on good R should be the weighted average of taxes elsewhere in the economy, with the weights being equal to the compensated derivatives of demand for each good with respect to the price of good R. This result is the same as that obtained by Dixit and Newbery (1985) and can be explained in terms of setting the tax on good R in a way that minimizes the effects of the distorted relative prices. Dixit and Newbery point out that there is no guarantee that all the weights are positive, and so the tax on R could be outside the range of the other taxes.

The introduction of road user costs has two effects. First, the taxes on R and S are not entirely distortionary: they are partly corrective. Therefore, it is only the distortionary part of the taxes, $(t_R - C_R)$ and $(t_S - C_S)$, that enter the equation. Second, the resource cost of consuming a unit of R or S is not just the producer price (which is scaled to unity) but also includes the marginal road use cost. Therefore, the distortionary element of the taxation of R is divided by $(1 + C_R)$ so that it is expressed as a proportion of its resource cost and the S_{GR} in the denominator of the right-hand side is multiplied by $(1 + C_S)$ to represent the resource cost of the substitution effect.

In summary, the taxation of an input into road use should consist of the marginal road use cost associated with that input plus an amount, given by the formula above, that represents an adjustment to take account of distortionary taxation elsewhere in the economy. This rule is derived

under the assumption that the government can levy lump-sum taxes. If, on the contrary, there is a need for distortionary revenue raising taxes, additional taxation of inputs into road use may be justified by the criteria discussed in Section 3 of this paper.

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